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(54) Object detecting device with a pyroelectric sensor

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FIG. 1

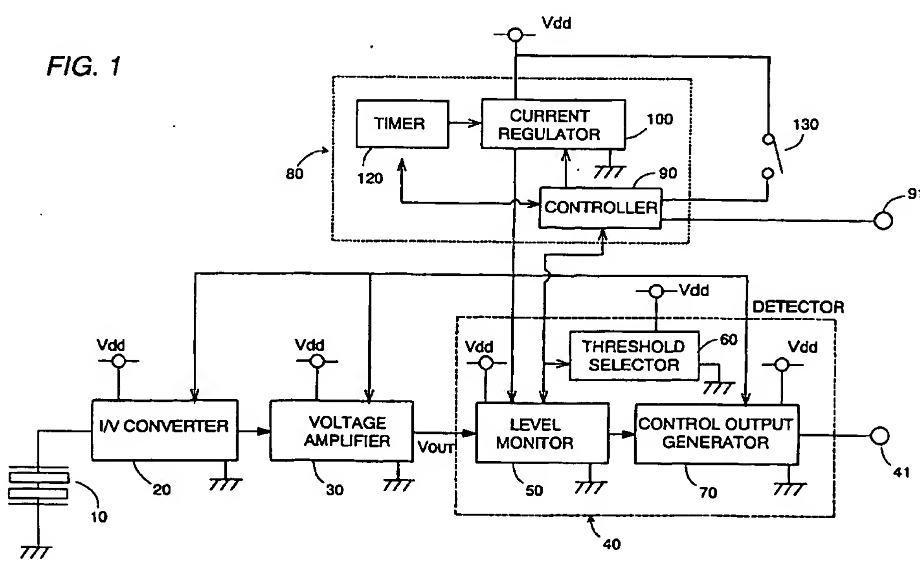

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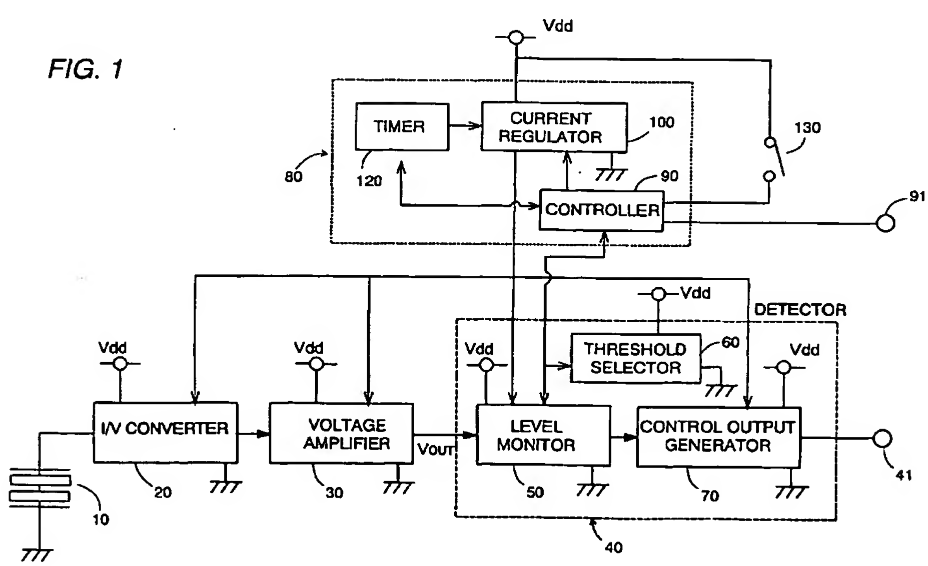
FIG. 1



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make a dedicated function such as turning on an illumination appliance in response to the control output, thereby reducing the power consumption.

[0006] In order to start the device rapidly for reliable detection, the mode selector is preferred to supply an initialization current greater than the rated source current to the voltage amplifier only for a predetermined initialization time period immediately upon energization of the device. Further, the mode selector is preferred to select the rest mode for a predetermined stabilization time period immediately subsequent to the initialization time period, and to switch the rest mode into the standby mode thereafter. Thus, the voltage amplifier inherently requiring much initialization current can be rapidly made ready for reliable operation. After the stabilization time period, the components of the device can be made stable to be ready for reliable detection, while eliminating a possibility of causing erroneous circuit operation leading to a false detection due to unstable outputs of the voltage amplifier during the stabilization time period.

[0007] The voltage amplifier may be of two-stage amplifier having a front-stage amplifying section and a rear-stage amplifying section. In this connection, the mode selector is configured to supply the limited source current to the front-stage and rear-stage amplifying sections in the standby mode, and supply the limited source current to the front-stage amplifying section and the rated source current to the rear-stage amplifying section in the operation mode. With the use of the two-stage amplifier and the associated scheme of only changing the level of the current being fed to the rear-stage amplifying section, it is made possible to further reduce the power consumption as compared to a case where the entire current to the amplifier is changed from the limited level to the rated level.

[0008] Further, the voltage amplifier is preferred to generate the rated voltage output which saturates at a level just above the detection threshold for the purpose of minimizing the power consumption in the operation mode, yet retaining reliable detection.

[0009] Preferably, the threshold selector includes a first voltage divider providing the preliminary threshold from a reference voltage and a second voltage divider providing the detection threshold from the same reference voltage. The first voltage divider is composed of a series combination of first resistors, while the second voltage divider is composed of a series combination of second resistors. The first resistor is selected to have a higher resistance than the second resistor in order to realize an advantageous effect of reducing the power consumption made at the first voltage divider to give the preliminary threshold with the use of the first resistors of high resistance, while enabling the second voltage divider to give the detection threshold accurately with the use of the second resistors of low resistance. Because of that first and second resistors are preferably selected from those that can be integrated in a chip for circuit miniaturization of the device, and also because of that the resistors of the type available can give an accurate resistance value as the intended resistance lowers, the second voltage divider makes the use of the second resistors of low resistance to provide the accurate the detection threshold for reliable object detection therewith, while the first voltage divider can consumes less power with the use of the first resistors of high resistance in providing the preliminary threshold which is not critical for object determination and could be rough as compared to the detection threshold. For instance, the first resistor may be selected from a non impurity-doped polysilicon resistor and a MOS (metal oxide semiconductor) transistor, while the second resistor may be selected from an impurity-doped polysilicon resistor.

[0010] These and still other objects and advantageous features of the present invention will become more apparent from the following description of a preferred embodiment when taken in conjunction with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG 1 is a block diagram showing a circuit of an object detecting device in accordance with a preferred embodiment of the present invention;

FIG. 2 is a circuit diagram showing a current regulator and its associated circuits of the above device;

FIG. 3 is a circuit diagram of a voltage amplifier utilized in the above device;

FIG. 4 is a waveform chart illustrating the operation of the above device;

FIG. 5 is a waveform chart illustrating an operation of the mode selector;

FIG. 6 is a circuit diagram of a threshold selector utilized in the above device;

FIG. 7 is a circuit diagram showing a modified current regulator and its associated circuit applicable to the above device; and

FIG. 8 is a circuit diagram of a voltage amplifier utilized in connection with the above modified current regulator.

MODE FOR CARRYING OUT THE INVENTION

[0012] Referring now to FIG. 1, there is shown an object detecting device in accordance with a preferred embodiment of the present invention. The device is utilized for surveillance of a room or the like space and is adapted to be interlocked with an external device such as an illumination appliance, an alarm and the like for activating the external device upon detection of a human body in the room. The device utilizes a pyroelectric sensor **10** which generates a sensing current in proportion to changes in the amount of incident infrared radiation from the human body. The sensing current is fed to an I/V converter **20** where it is converted into a corresponding

voltage. The voltage is then amplified at a voltage amplifier **30** to provide a voltage output to a detector **40** for detection of the human body. The amplifier **30** has an offset voltage V_{OFT} around which the voltage output V_{OUT} varies, as shown in FIG. 4, in proportion to the amount of the sensing current from the pyroelectric sensor **10**.

[0013] The detector **40** includes a level monitor **50**, a threshold selector **60** providing two thresholds, namely, a preliminary threshold TH_1 and a detection threshold TH_2 ($>TH_1$) to the level monitor **50**, and a control output generator **70**. The voltage output V_{OUT} from the amplifier **30** is compared at the level monitor **50** selectively with TH_1 ($-TH_1$) and TH_2 ($-TH_2$) to generate a wake-up signal when the voltage output satisfies a relation that $V_{OUT} > TH_1$ or $V_{OUT} < -TH_1$, and to generate a detection signal when the voltage output satisfies a relation that $V_{OUT} > TH_2$ or $V_{OUT} < -TH_2$. The control output generator **70** is provided to issue, in response to the detection signal, a control output at an output terminal **41** for activating the external device. As will be discussed later, the wake-up signal is utilized to switch a standby mode, which is a default mode of consuming less power, to an operation mode for reliable detection of the object. The standby mode is defined to provide a limited source current to the I/V converter **20**, the voltage amplifier **30**, the level monitor **50**, and the control output generator **70** for activating the same at a minimum performance level, while the operation mode is defined to provide a rated source current higher than the limited current to the same for activating the same at its full capability to obtain a reliable and consistent detection result.

[0014] For this purpose, the device is provided with a mode selector **80** which includes a controller **90**, a current regulator **100**, and a timer **120**. The controller **90** is provided to switch the standby mode to the operation mode and vice versa. The current regulator **100** is configured to flow source currents of different levels designated by the controller **51**. The source currents includes the limited source current of about 0.03 µA to 0.09 µA, for example, the rated source current of about 0.18 µA to 0.6 µA, for example, and an initialization current higher than the rated current. As shown in FIG. 2, the current regulator **100** includes a constant current supply **101**, a plurality of FETs **102** to **107**, and switches **111** to **113**. The constant current supply **101** supplies a reference current I_{101} from a power source Vdd through FET **102**, while a series combination of FETs **103** and **104** is connected across the series combination of the current supply **101** and FET **102** to flow a mirror current I_{103}. Connected across FET **104** are three sets of series combinations each composed of each one of switches **111** to **113** and each one of FETs **105** to **107**, as illustrated, such that the mirror current I_{103} can vary by selective closing and opening of switches **111** to **113**. As the mirror current I_{103} varies, the I/V converter **20**, the voltage amplifier **30**, the level monitor **50**, and control output generator **70** that are connected to receive a correspondingly varied voltage will be supplied with one of the limited source current, the rated source current, and the initialization source current. For instance, as illustrated in the figure, the voltage amplifier **30** includes two FETs **33** and **34** of which gates are connected to receive the voltage corresponding to the mirror current I_{103} in order to flow currents I_{33} and I_{34} as one of the limited source current, the rated source current, and the initialization source current from the power source Vdd. Whereby, the voltage amplifier **30** can be selectively made to provide the restricted voltage output proportional to the voltage from the I/V converter **20**, to provide the rated voltage output proportional to the voltage from the I/V converter **20**, and to complete the initialization, as will be discussed later.

[0015] As shown in FIG 3, the voltage amplifier **30** is of a two-stage amplifier including a front-stage amplifying section **31** and a rear-stage amplifying section **32**. These sections **31** and **32** include current regulating FETs **33** and **34** which respond to the mirror current I_{103} flowing through the current regulator **100** for flowing the source currents I_{33} and I_{34} from the power source Vdd to the front-stage amplifying section **31** and the rear-stage amplifying section **32**, respectively. The gates of FETs **31** and **32** are commonly connected to receive the voltage corresponding to the mirror current I_{103} at a current control input **35**. The front-stage amplifying section **31** includes a reference voltage input **36** for receiving a predetermined reference voltage and a voltage input **37** for receiving the voltage from the I/V converter **20** to amplify the same. The rear-stage amplifying section **32** includes an output terminal **38** for providing the amplified output to the level monitor **50**.

[0016] Also, the I/V converter **20** is of two-stage configuration having two parallel current regulating FETs **23** and **24** which are connected between the power source Vdd and the ground and of which gates are connected to receive the voltage corresponding to the current I_{103} in order to flow currents I_{23} and I_{24} as one of the limited source current, the rated source current, and the initialization source current, thereby providing the corresponding output to the voltage amplifier **30**. Likewise, the level monitor **50** and the output controller **70** include current regulating FETs **53** and **73** respectively in order to flow individual currents I_{53} and I_{73} as one of the above different source currents. It is noted in this connection that these source currents I_{33}, I_{34}, I_{23}, I_{24}, I_{53} and I_{73} may be made different from each other by selecting the corresponding FETs of different characteristics.

[0017] The controller **90** is normally set to make the standby mode in which the current regulator **100** responds to flow the limited source currents, and the threshold selector **42** is normally set to give the preliminary threshold TH_1 to the level monitor **50** so that the level monitor **50** takes the voltage output V_{OUT} as the restricted voltage from the voltage amplifier **30**, i.e., the voltage of low amplification and compares it with the preliminary threshold TH1. When it is found that $V_{OUT} > TH_1$

or $V_{OUT} < -TH_1$, as shown in FIG. 4, the level monitor **50** provides the wake-up signal to the threshold selector **60** as well as to the controller **90** of the mode selector **80**. Upon this occurrence, the threshold level selector **60** gives the detection threshold VTH_2 to the level monitor **50**, and at the same time the controller **90** selects the operation mode to cause the amplifier **30** to provide the voltage output V_{OUT} as the rated voltage output, i. e., the voltage of high amplification. Thus, the level monitor **50** is enabled to compare the voltage output V_{OUT} with the detection threshold TH_2 and issue the detection signal when $V_{OUT} > TH_1$ or $V_{OUT} < -TH_1$. The detection signal is indicative of the presence of the human body and is converted into the control signal for activating the external device.

[0018] When the detection signal is issued, the controller **90** responds to activate the timer **120** to start counting time and switches the operation mode back to the standby mode after the timer counting a predetermined time frame **T**, thereby making the device to be ready for checking the next wake-up signal. In addition, the controller **90** constantly checks whether or not subsequent detection signal is issued within the time frame **T**, and resets the timer **120** to start counting time each time the subsequent detection signal is acknowledged within the time frame **T**, thereby extending the time frame T so long as the detection signal appears successively for notifying such event to the external device.

[0019] The controller **90** is optionally provided with a reset terminal **91** for receiving a reset signal from the external device. When connecting the rest terminal **91** to the external device, the controller **90** is set to select a rest mode once the detection signal is acknowledged and keeps the rest mode until receiving a reset signal from the external device. The rest mode is defined to keep supplying the limited source current to the I/V converter **20**, the amplifier **30**, the level monitor **50**, and the control output generator **70**, and at the same time disabling the level monitor **50**, i.e., neglecting the result of the level monitor **50**. Thus, it is possible to minimize the power consumption while the external device is responding, yet avoiding the occurrence of the wake-up signal which would provoke the operation mode. This is particularly advantageous when the external device is only required to activate for a limited time interval in response to the first advent of the detection signal.

[0020] In order to reduce the power consumption at the amplifier **30** once the detection signal is issued, the amplifier **30** may be selected to saturate the voltage output V_{OUT} just above the detection threshold TH_2 or just below $-TH_2$ when supplied with the rated source current, as shown in FIG. 5.

[0021] As shown in FIG. 6, the threshold selector **60** includes a first voltage divider providing the preliminary threshold TH_1 and a second voltage divider providing the detection threshold TH_2 to the level monitor **50**. The first voltage divider is a series combination of first resistors **61** connected in series with a switch **63** between the power source Vdd and the ground, while the second voltage divider is a series combination of second resistors **62** connected in series with a switch **64** between the power source and the ground. The connection between the first resistors **61** is connected through a switch **65** to the level monitor **50**, while the connection between the second resistors **62** is connected through a switch **66** to the level monitor. Normally, the switches **63** and **65** are closed to provide the preliminary threshold TH_1 to the level monitor **50**. When receiving the wake-up signal from the level monitor **50**, the switches **64** and **66** are closed to provide the detection threshold TH_2 to the level monitor **50**. In view of that the preliminary threshold may be rough as it does not critical to the detection of the human body, while the detection threshold have to be accurate for reliable detection, and also that available resistors elements capable of being integrated in a semiconductor chip together with other electronic components of the device exhibit more accurate resistance value as the resistance value lowers, it is contemplated in the present invention to use the first resistors **61** having the higher resistance and the second resistors **62** of lower resistance. Whereby, it is possible to give the reliable human detection with the accurately determined detection threshold, yet reducing the power consumption in providing the preliminary threshold with the use of the first resistors of high resistance. For instance, the first resistor **61** is selected from a non impurity-doped polysilicon resistor or MOS (metal oxide semiconductor) transistor, while the second resistor **62** is selected from impurity-doped polysilicon resistor.

[0022] Further, the device is designed to become stable rapidly upon being energized for immediate and reliable object detection. For this purpose, the controller **90** responds to the throw-in of a power switch **130** of the device for providing an initialization time period during which the initialization current higher than the rated current is allowed to flow in the I/V converter **20** and the voltage amplifier **30** for rapidly making these high current-consuming circuits operative, and the limited current is allowed to flow to the level monitor **50** and the control output generator **60** of less current-consuming circuits. Immediately thereafter, the controller **90** selects the rest mode of disabling the output of the level monitor **50** for a predetermined stabilization time during which the limited source current is supplied to make the whole circuits stable to be ready for reliable detection free from any erroneous operation due to unstable outputs from the individual circuits, particularly from the I/V converter **20** and the voltage amplifier **30**. Thereafter, the controller **90** switches the rest mode to the standby mode, enabling the output of the level monitor **50** for making the intended operation of detecting the human body.

[0023] FIGS. 7 and 8 show a modified current regulator **100A** and associated circuits which are similar to those utilized in the above embodiment but are configured to switch the current being supplied to the rear-stage amplifier of the I/V converter **20** and the rear-stage

amplifier of the voltage amplifier **30**, while constantly flowing the limited source current to the front-stage amplifiers of the I/V converter **20**, the front-stage amplifier of the voltage amplifier **30**, the level monitor **50**, and the control output generator **70**. In this connection, the amplifier **30** is configured, as shown in FIG. 8, so that FET **33** of the front-stage amplifying section **31** and FET **34** of the rear-stage amplifying section **32** have individual gates to receive currents I_{103A} and I_{103B} of different levels or different voltage from the current regulator **100A**, respectively through current control inputs **35A** and **35B**. As shown in FIG. 7, the current regulator **100A** includes, in addition to a series combination of a constant current supply **101A** and FET **102A** connected across the power source Vdd, a front-end current generator **121** composed of FETs **103A, 104A** and **105A** and a switch **111A** to provide a front-end mirror current I_{103A}, and a rear-end current generator **122** composed of FETs **103B, 104B** and **105B**, and switches **111B, 112B** and **113B** to provide a rear-end mirror current I_{103B}. The front-end mirror current I_{103A} is applied as a corresponding voltage to the gate of current regulating FET **23** of the front-stage amplifying section **21** of the I/V converter **20**, the gate of current regulating FET **33** of the front-stage amplifying section **31** of the amplifier **30**, the gate of current regulating FET **53** of the level monitor **50**, and the gate of the current regulating FET **73** of the control output generator **70** in order to flow the limited source currents I_{23}, I_{33}, I_{53}, and I_{73} from the power source Vdd to the individual circuits **20, 30, 50,** and **70.** Likewise, the rear-end mirror current I_{103B} is applied as a corresponding voltage to the gate of current regulating FET **24** of the rear-stage amplifying section **22** of the I/V converter **20**, the gate of current regulating FET **34** of the rear-stage amplifying section **32** of the amplifier **30** in order to flow currents I_{24} and I_{34} from the power source Vdd to the rear-stage amplifying sections as one of the limited source current, rated source current, and the initialization current by selective activation of the switches **111B, 112B,** and **113B.**

[0024] In the absence of the wake-up signal from the level monitor **50**, the controller **90** of the mode selector **80** sets the switches **111B, 112B,** and **113B** of the rear-end current generator **122** to make the rear-end mirror current I_{103B} nearly equal to the front-end mirror current I_{103A}, thereby flowing the limited source current I_{24} and I_{34}, which are nearly equal to those currents I_{23}, I_{33}, I_{53}, I_{73} caused by the front-end mirror current I_{103A}, to the rear-stage amplifying sections of the I/V converter **20** and the amplifier **30.** When the wake-up signal is acknowledge, the controller **90** is switched to provide the rear-end mirror current I_{103B} larger than the front-end mirror current I_{103A}, thereby flowing the rated source current I_{24} and I_{34}, which are greater than those currents I_{23}, I_{33}, I_{53}, I_{73} caused by the front-end mirror current I_{103A}, to the rear-stage amplifying section of the I/V converter **20** and the amplifier **30.** Thus, when the device is switched into the operation mode, the rated currents of high level can be supplied only to the rear-stage amplifying sections of the I/V converter **20** and the amplifier **30** for the intended performance, thereby avoiding unnecessary high current consumption otherwise made at the front-stage amplifying sections. The high initialization current required at the very beginning of energizing the device can be fed only to the rear-stage amplifying sections of the I/V converter **20** and the amplifier **30** while the limited source currents are fed to the front-stage amplifying sections of the I/V converter **20** and the amplifier **30**, as well as to the level monitor **50** and the control output generator **70**. In this sense, the current regulator **100A** is also configured to provide the initialization current higher than the rated source current by selective activation of switches **111B** to **113B.**

[0025] The features disclosed in the foregoing description, in the claims and/or in the accompanying drawings may, both separately and in any combination thereof, be material for realising the invention in diverse forms thereof.

Claims

1. An object detecting device comprising:

    a pyroelectric sensor (10) generating a sensing current in accordance with changes in the amount of infrared radiation incident on said sensor from an object;
    an I/V converter (20) which converts said sensing current from said pyroelectric sensor into a corresponding voltage;
    a voltage amplifier (30) which amplifies said voltage from the I/V converter into an amplified voltage;
    a detector (40) including a level monitor (50) which compares said amplified voltage with a predetermined detection threshold (TH_2) to provide a detection signal when said amplified voltage satisfies a detection criterion with regard to said threshold, said detector responding to said detection signal for issuing a control output which is indicative of the detection of the object and is adapted to actuate an external device;

    characterized in that

    said voltage amplifier provides a restricted voltage output of low amplitude when receiving a limited source current and provides a rated voltage output of high amplitude when receiving a rated source current greater than said limited source current,

    said detector includes a threshold selector (60) which has said detection threshold (TH_2) and a preliminary threshold (TH_1) lower than said detection threshold, and which is normally set to provide

the preliminary threshold to said level monitor,

said level monitor compares said restricted voltage output from said voltage amplifier with the preliminary threshold to provide a wake-up signal when the restricted voltage output satisfies a preliminary criteria with regard to said preliminary threshold;

said threshold selector switches said preliminary threshold to said detection threshold in response to said wake-up signal; and

said device further includes a mode selector (80) which, in response to the wake-up signal, provides an operation mode for supplying said rated source current from a power source to said voltage amplifier such that said level monitor compares the rated voltage output with said detection threshold for detection of the object, and otherwise provides a standby mode for supplying said limited source current to said voltage amplifier from said power source.

2. The object detecting device as set forth in claim 1, wherein

said mode selector (80) keeps said operation mode continuously for a predetermined time frame from the first advent of the detection signal and switches back forcibly to the standby mode thereafter.

3. The object detecting device as set forth in claim 2, wherein

said mode selector (80) resets said time frame to start each time said detection signal is followed by another detection signal within said time frame.

4. The object detecting device as set forth in claim 1, wherein

said mode selector has a reset input (91) for receiving a reset signal from said external device, said mode selector switching said operation mode forcibly into a rest mode for keeping said limited source current to supply to said voltage amplifier from said power source and at the same time disabling said level monitor upon seeing the first advent of said detection, and keeping said rest mode until receiving said reset signal at said reset input.

5. The object detecting device as set forth in claim 1, wherein

said mode selector supplies an initializing current greater than said rated current to said voltage amplifier only for a predetermined initialization time period immediately upon energization of the device.

6. The object detecting device as set forth in claim 5, wherein

said mode selector selects a rest mode of supplying said limited source current to said amplifier while disabling said level monitor for a predetermined stabilization time period immediately subsequent to said initialization time period, and switches the reset mode into said standby mode thereafter.

7. The object detecting device as set forth in claim 7, wherein

said voltage amplifier (30) is of two-stage amplifier having a front-stage amplifying section (31) and a rear-stage amplifying section (32),

said mode selector supplying said limited source current to said front-stage and rear-stage amplifying sections in said standby mode, and supplying said limited source current to said front-stage amplifying section and supplying said rated source current to said rear-stage amplifying section in said operation mode.

8. The object detecting device as set forth in claim 1, wherein

said voltage amplifier provides said rated voltage output which saturates at a level just above said detection threshold.

9. The object detecting device as set forth in claim 1, wherein

said mode selector supplies the limited source current to said I/V converter (20) in said standby mode, and supplies the rated source current to said I/V converter in said operation mode.

10. The object detecting device as set forth in claim 1, wherein

said threshold selector (60) comprises a first voltage divider composed of a series combination of first resistors (61) to provide said preliminary threshold (TH_1) from a reference voltage, and a second voltage divider composed of a series combination of second resistors (62) to provide said detection threshold (TH_2) from said reference voltage source, said first resistors having higher resistance than said second resistors.

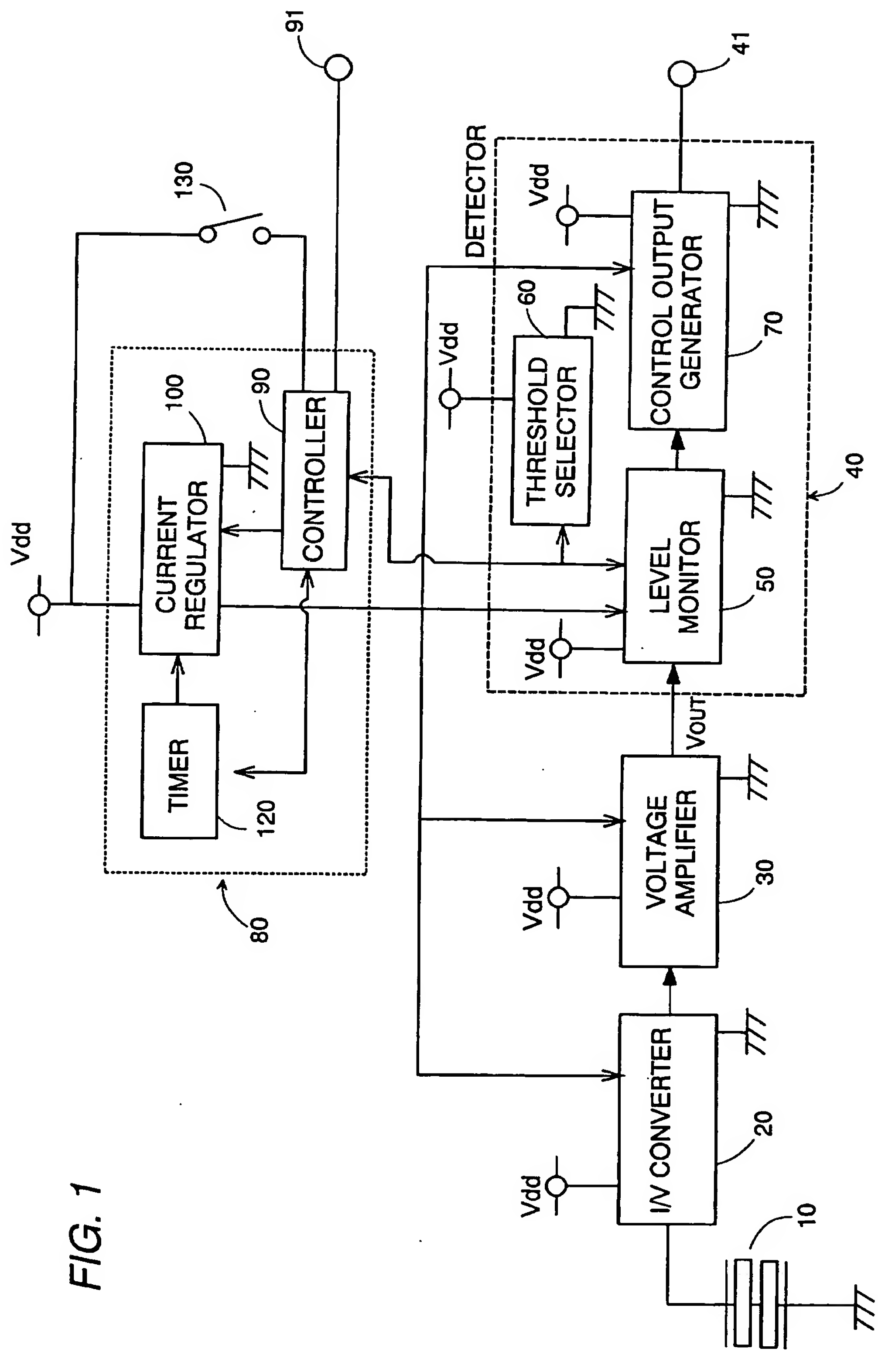
11. The object detecting device as set forth in claim 10, wherein

said first resistor is selected from a non impurity-doped polysilicon resistor, while said second resistor is selected from an impurity-doped polysilicon resistor.

12. The object detecting device as set forth in claim 10, wherein

said first resistors is selected from a MOS transistor, while said second resistor is selected from an impurity doped polysilicon resistor.

FIG. 1


CURRENT REGULATOR
CONTROLLER
TIMER
THRESHOLD SELECTOR
CONTROL OUTPUT GENERATOR
LEVEL MONITOR
DETECTOR
VOLTAGE AMPLIFIER
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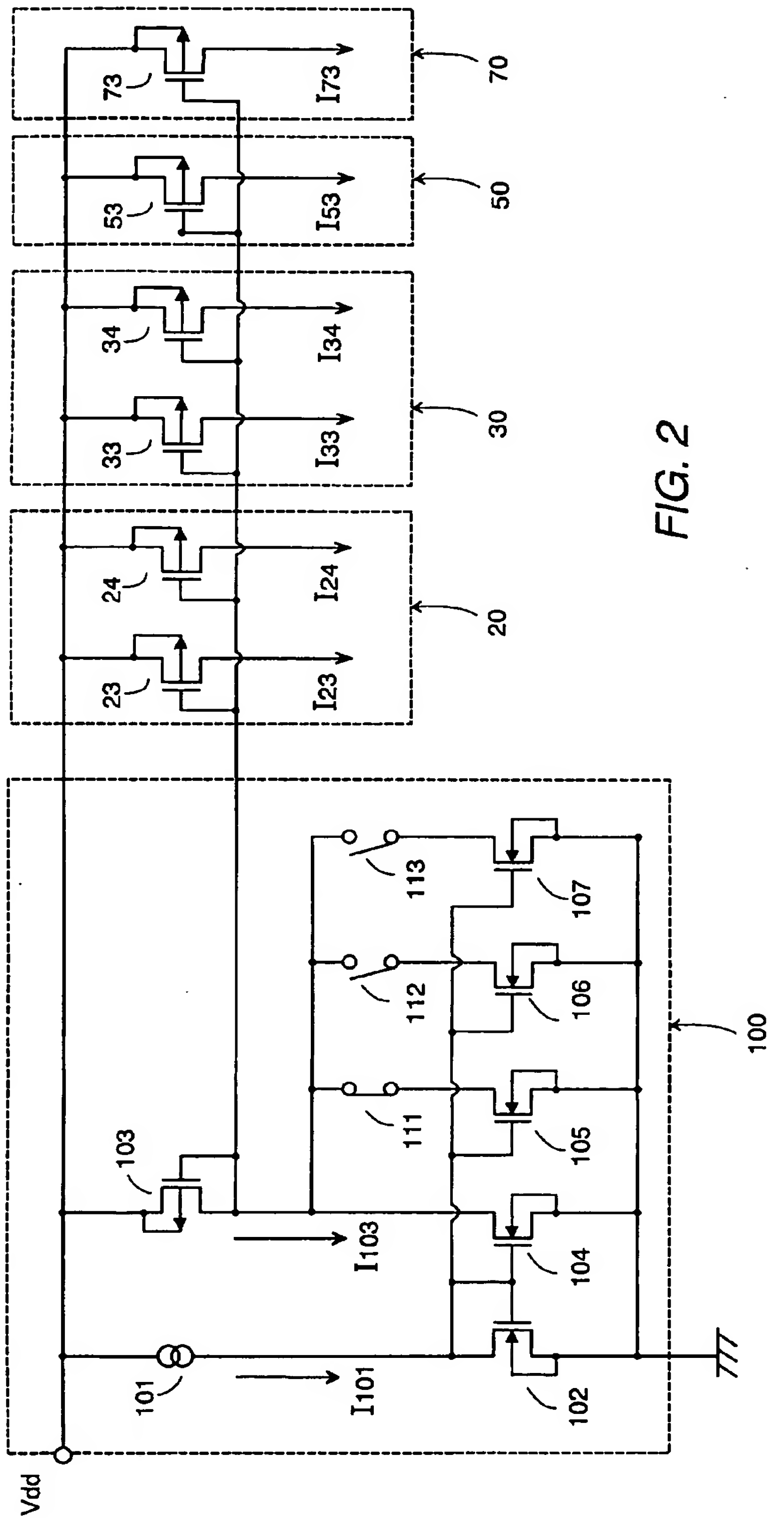

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FIG. 2

FIG. 3

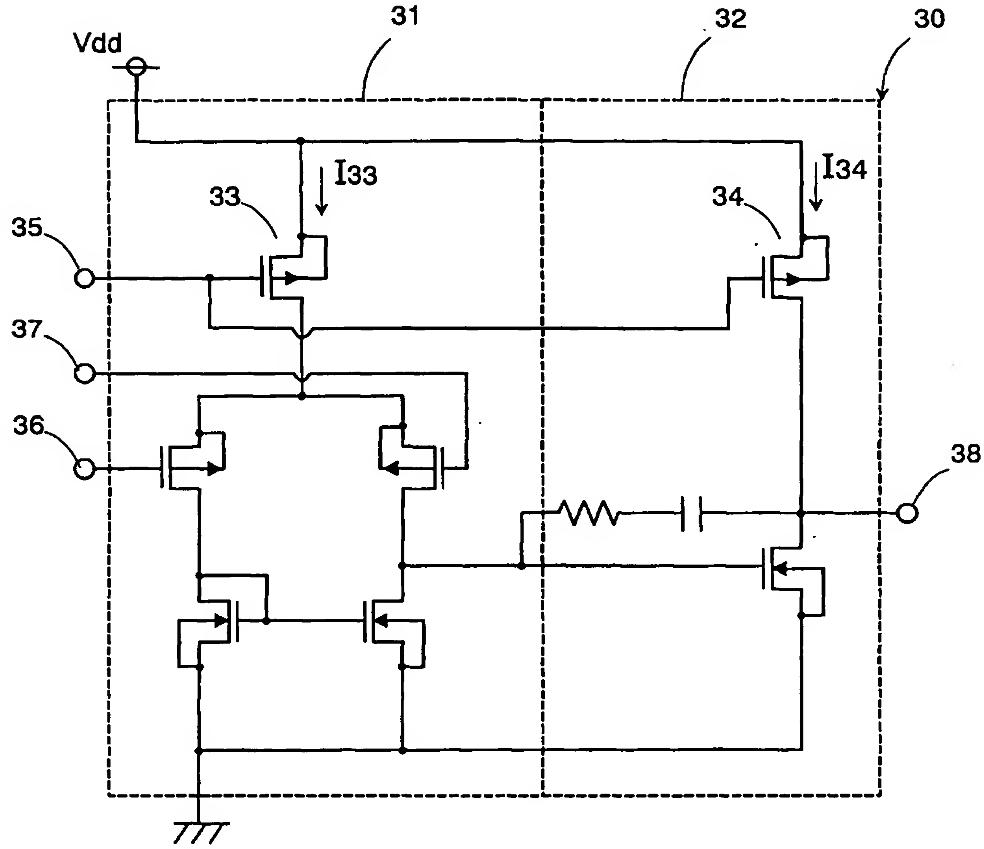

31
32
30
Vdd
I33
I34
33
34
35
37
36
38

FIG. 5

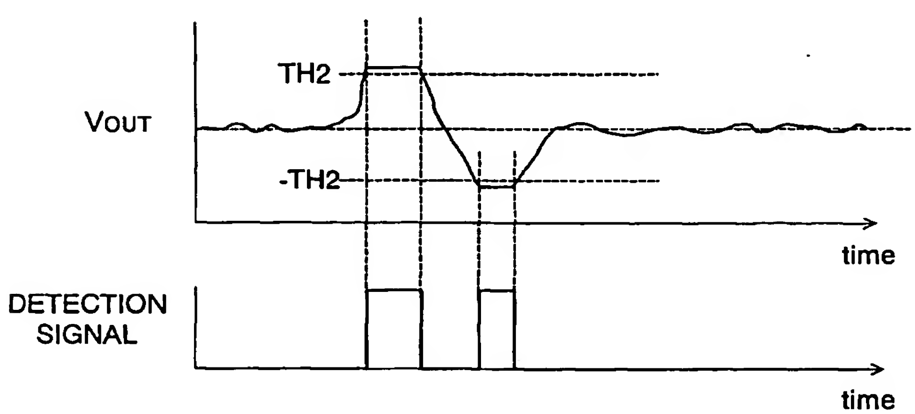

TH2
VOUT
-TH2
time
DETECTION SIGNAL
time

FIG. 4

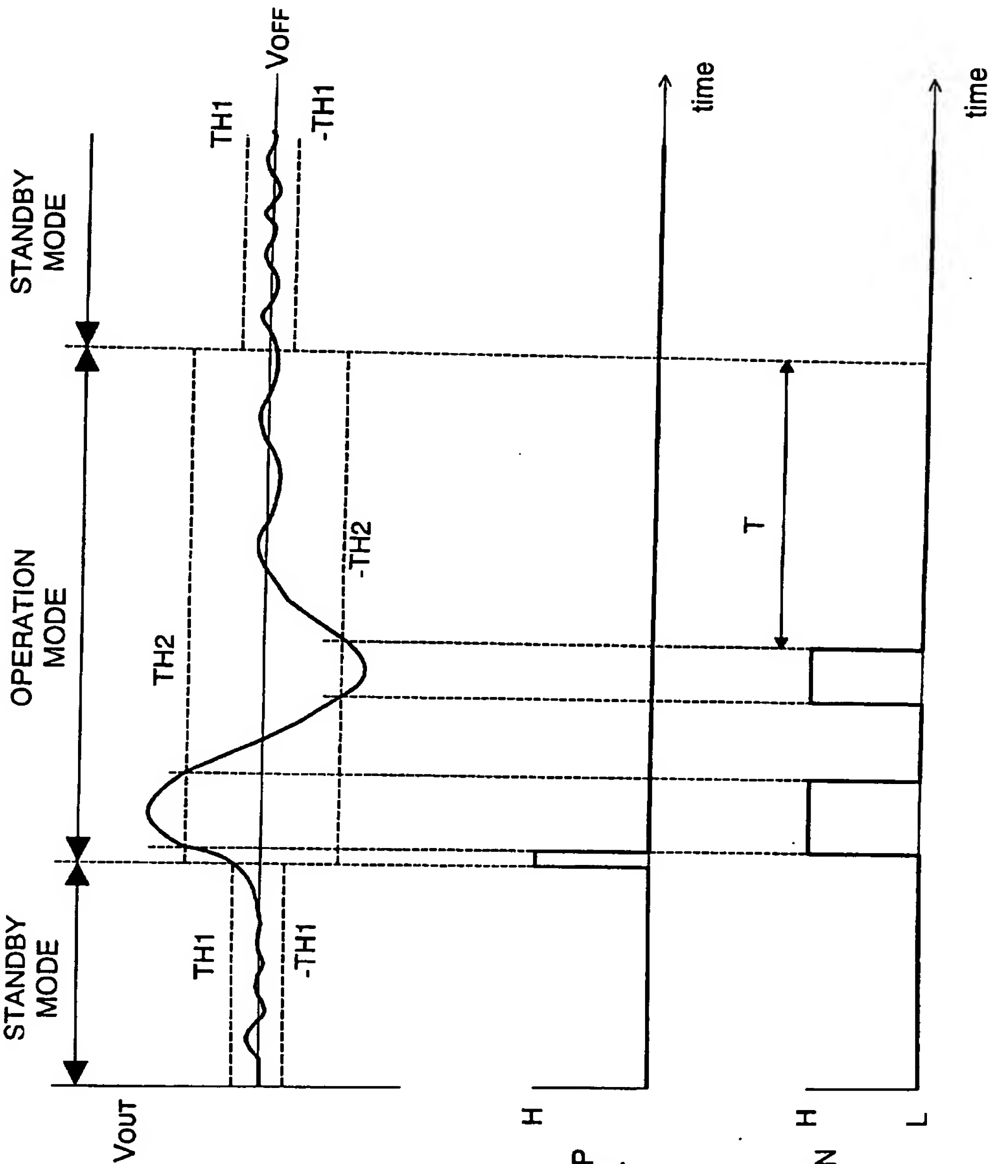

STANDBY MODE
OPERATION MODE
STANDBY MODE
VOUT
TH1
-TH1
TH2
-TH2
TH1
-TH1
VOFF
time
H
WAKE-UP SIGNAL
T
H
L
DETECTION SIGNAL
time

FIG. 6

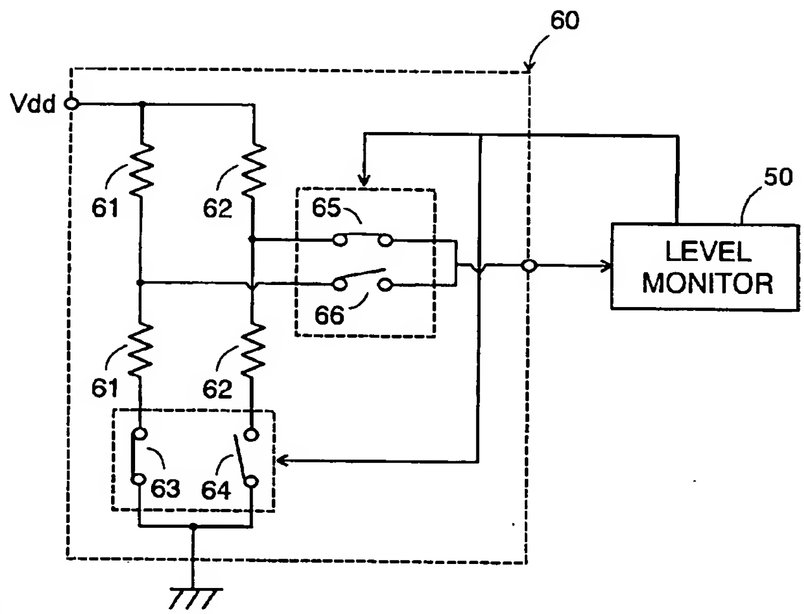

60
Vdd
61
62
65
50
LEVEL MONITOR
66
61
62
63
64

FIG. 8

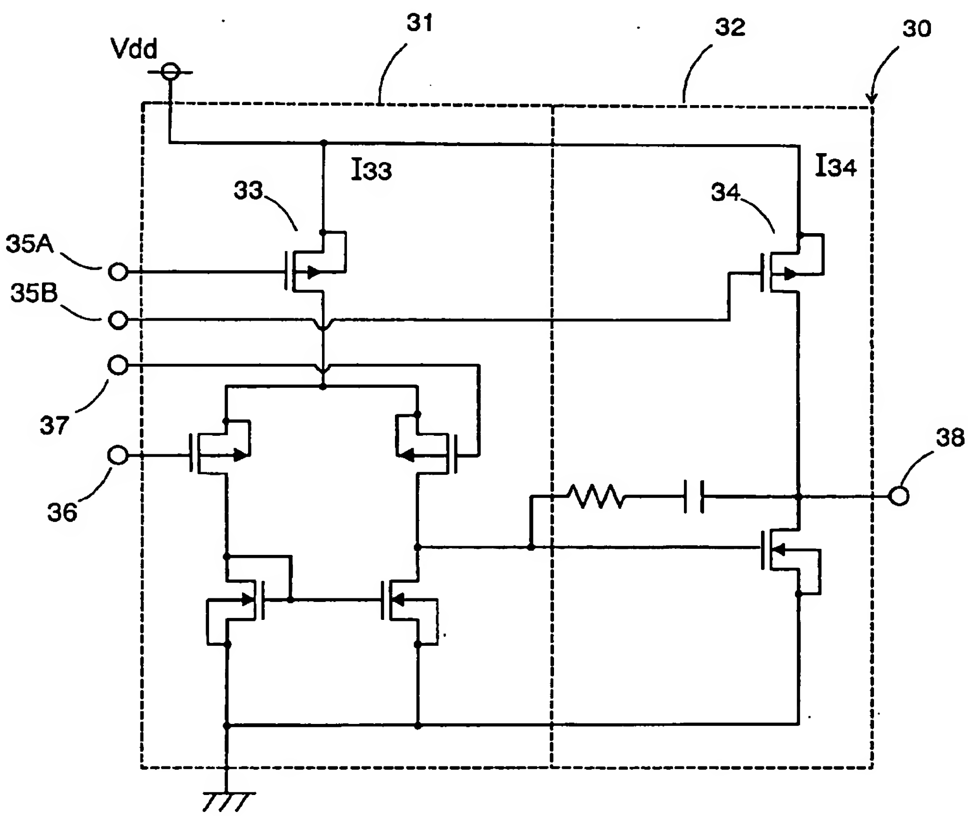
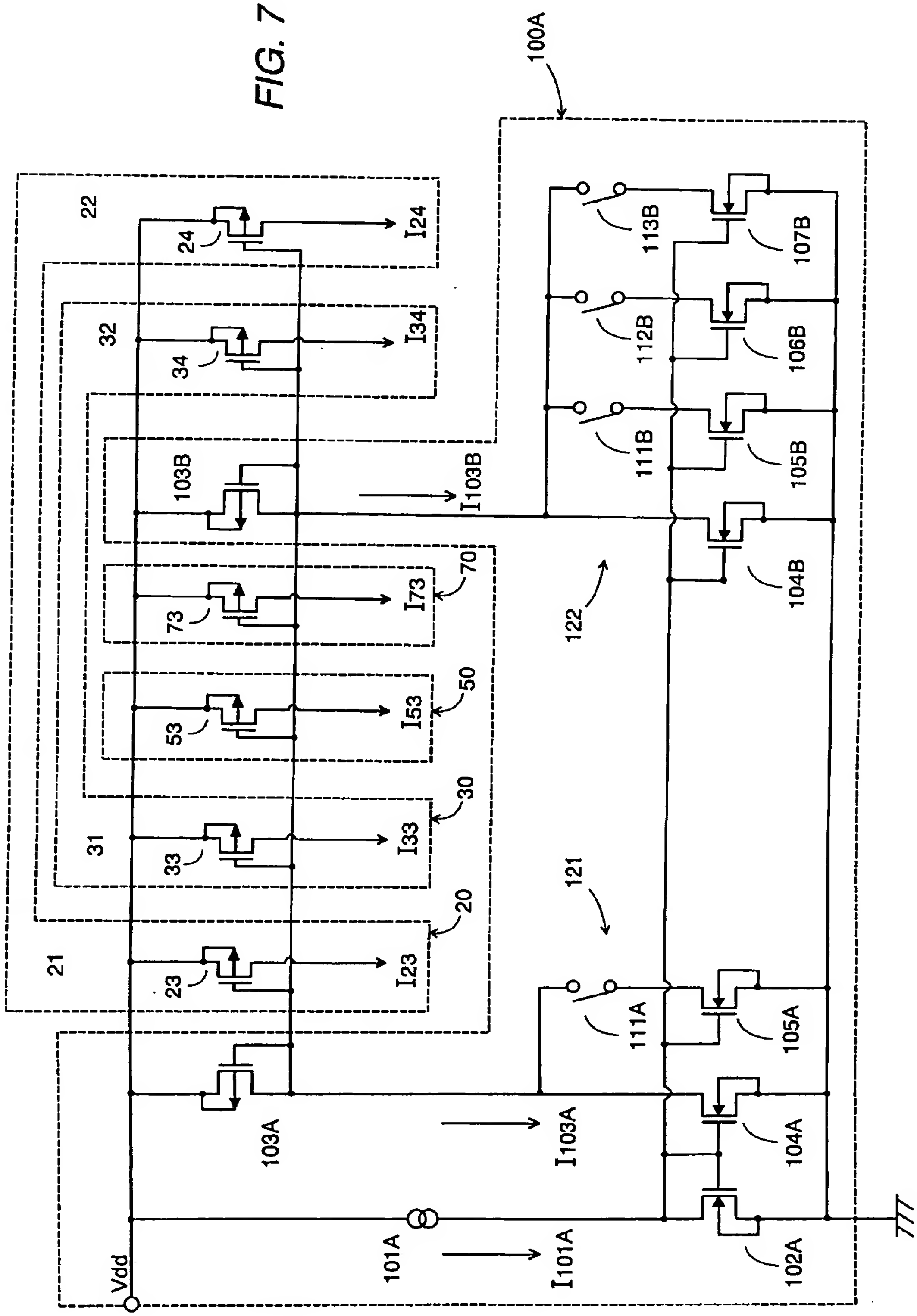

Vdd
31
32
30
I33
I34
33
34
35A
35B
37
36
38

FIG. 7


100A
22
24
I_{24}
32
34
I_{34}
103B
I_{103B}
70
73
I_{73}
50
53
I_{53}
30
31
33
I_{33}
20
21
23
I_{23}
103A
I_{103A}
101A
I_{101A}
Vdd
113B
107B
112B
106B
111B
105B
104B
122
121
111A
105A
104A
102A